CLAIMS

What is being claimed is:

1. A light emitting device comprising:

a III-nitride semiconductor structure including an active region disposed between an n-type and a p-type region; and

a photonic crystal structure formed in at least a portion of the n-type region; and

a reflector disposed on at least a portion of a surface of the p-type region opposite the active region.

2. The device of claim 1 wherein the photonic crystal structure comprises a periodic variation in a thickness of the n-type region.

3. The device of claim 2 wherein a ratio of the period of the periodic structure and the wavelength of light emitted by the active region in air is about 0.1 to about 5.

4. The device of claim 1 wherein the photonic crystal structure comprises a planar lattice of holes.

5. The device of claim 4 wherein the holes have a depth between about 0.05 λ and about 5 λ, where λ is a wavelength in the III-nitride semiconductor structure of light emitted by the active region.

6. The device of claim 4 wherein a lattice type, lattice constant, hole diameter, and hole depth are selected to create a predetermined radiation pattern.

7. The device of claim 6 wherein greater than 50% of radiation exiting the device is emitted in an exit cone defined by an angle of 45 degrees to an axis normal to a surface of the device.

8. The device of claim 4 wherein the planar lattice is selected from the group consisting of a triangular lattice, a square lattice, a hexagonal lattice, and a honeycomb lattice.

9. The device of claim 4 wherein the planar lattice includes more than one lattice type.

10. The device of claim 4 wherein the lattice has a lattice constant a between about 0.1 λ and about 10 λ, where λ is a wavelength in the III-nitride semiconductor structure of light emitted by the active region.

11. The device of claim 4 wherein the lattice has a lattice constant a between about 0.1 λ and about 4 λ, where λ is a wavelength in the III-nitride semiconductor structure of light emitted by the active region.

12. The device of claim 4 wherein the lattice has a lattice constant a and the holes have a diameter between about 0.1a and about 0.5a.

13. The device of claim 4 wherein the holes are filled with a dielectric.

14. The device of claim 13 wherein the dielectric has a dielectric constant between about 1 and about 16.

15. The device of claim 1 wherein a distance between the reflector and the photonic crystal structure is between about λ and about 5λ, where λ is a wavelength in the III-nitride semiconductor structure of light emitted by the active region.

16. The device of claim 1 wherein a distance between a center of the active region and the photonic crystal structure is less than about 4λ, where λ is a wavelength in the III-nitride semiconductor structure of light emitted by the active region.

17. The device of claim 1 wherein a total thickness of III-nitride semiconductor layers in the device is less than about 1 μm.

18. The device of claim 1 wherein a total thickness of III-nitride semiconductor layers in the device is less than about 0.5 μm.

19. The device of claim 1 wherein a thickness of the n-type region, the active region, and the p-type region is less than about 1 μm.

20. The device of claim 1 wherein a thickness of the n-type region, the active region, and the p-type region is less than about 0.5 μm.

21. The device of claim 1 wherein at least a portion of the reflector underlies the photonic crystal structure.

22. The device of claim 1 further comprising a host substrate bonded to the reflector.

23. The device of claim 22 further comprising a metal bonding layer disposed between the host substrate and the reflector.

24. The device of claim 23 wherein the metal bonding layer comprises gold.

25. The device of claim 22 wherein the host substrate comprises one of Si, GaAs, Cu, Mo, W, and alloys thereof.

26. The device of claim 1 wherein the reflector comprises silver.

27. The device of claim 1 wherein the photonic crystal structure is formed in a first portion of the n-type region, the device further comprising a contact formed on a second portion of the n-type region, the second portion being substantially free of the photonic crystal structure.

28. The device of claim 27 wherein the contact surrounds the photonic crystal structure.

29. The device of claim 1 further comprising:

a trench extending through the p-type region and the active region to the n-type region; and

a contact disposed on the n-type region within the trench.

30. The device of claim 29 wherein the contact and the photonic crystal structure are formed on opposite surfaces of the n-type region.

31. The device of claim 1 wherein the n-type region comprises a first n-type region, the device further comprising:

a second n-type region disposed between the photonic crystal structure and the active region.

32. The device of claim 1 wherein the photonic crystal structure extends into the active region.

33. The device of claim 32 wherein the photonic crystal structure extends into the p-type region.

34. A method of forming a semiconductor light emitting device, the method comprising:

growing a III-nitride semiconductor structure on a growth substrate, the III-nitride semiconductor structure including an active region disposed between an n-type and a p-type region;

bonding the III-nitride semiconductor structure to a host substrate;

removing the growth substrate; and

forming a photonic crystal structure in the n-type region of the III-nitride semiconductor structure.

35. The method of claim 34 wherein forming a photonic crystal structure comprises etching the photonic crystal structure in a surface of the n-type region exposed by removal of the growth substrate.

36. The method of claim 34 wherein the n-type region is a first n-type region and where forming a photonic crystal structure comprises:

etching the photonic crystal structure in the first n-type region after growth of the first n-type region;

growing a second n-type region over the photonic crystal structure; and

growing the active region and the p-type region over the second n-type region.

37. The method of claim 34 wherein:

growing a III-nitride semiconductor structure on a growth substrate comprises growing the p-type region overlying the growth substrate, growing the active region overlying the p-type region, and growing the n-type region overlying the active region;

the host substrate is a first host substrate; and

the first host substrate is bonded to the n-type region; the method further comprising:

after removing the growth substrate, bonding a second host substrate to the p-type region; and

removing the first host substrate.